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Growth Characteristics of Indigenous Norduz Female and Male Lambs

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ABSTRACT

The objectives of the present study were to compare the growth curve models for their ability to describe the growth of Turkish Norduz sheep, and to estimate the growth curve parameters by the selected growth model. The data were collected from 93 male lambs and 86 female lambs from birth to 198 day of age. Five different nonlinear models, Brody, Gompertz, Logistic, Bertalanffy and Negative exponential, were compared using coefficient of determination (R^2), asymptotic mature weight (BW_A), residual standard deviation (RSD) and coefficient of correlation (r) between the observed and estimated growth curves. The Logistic growth model was observed to be appropriate for explaining the growth of Norduz female and male lambs. Male lambs grew faster and attained larger mature weight than female lambs showing that sex is the main factor affecting the growth of Norduz lambs. Type of birth had no effect on the growth of the lambs.

Keywords: Norduz sheep; Growth parameters; Lamb growth

Norduz Dişi ve Erkek Kuzuların Büyüme Özellikleri

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ÖZET

Bu çalışmanın amacı, Norduz koyunlarının büyümesini tanımlama bakımından büyüme modellerinin karşılaştırılması ve belirlemede kullanılan büyüme modeline göre büyüme eğrisi parametrelerinin tahmin edilmesidir. Veri seti, 93 baş erkek ve 86 baş dişi kuzuya ait doğumdan 198 günlük yaş'a kadar canlı ağırlıkları kapsamıştır. Beş farklı doğrusal olmayan model (Brody, Gompertz, Logistic, Bertalanffy and Negative exponential model) belirleme katsayısı (R^2), ergin canlı ağırlık (BW_A), hata standart sapması (RSD) ve gözlenen ile tahmin edilen büyüme eğrisi arasındaki korelasyon katsayısı (r) kullanılarak karşılaştırılmıştır. Norduz erkek ve dişi kuzuların büyümelerini en iyi tanımlayan modelin Logistic büyüme modeli olduğu gözlenmiştir. Erkek kuzuların dişi kuzulara göre daha hızlı geliştikleri ve ergin canlı ağırlığa daha erken yaşta ulaştıkları gözlenmiştir. Cinsiyet, Norduz kuzuların büyümelerini etkileyen en önemli faktör olarak gözlenirken, doğum tipinin kuzuların büyümesi üzerine önemli bir etki yapmadığı gözlenmiştir.

Anahtar sözcükler: Norduz koyunu; Büyüme parametreleri; Kuzu gelişimi

1. Introduction

One of the most important traits is the growth in farm animals, like sheep. It can be describes as the increasing body cell numbers, or weight gain in a certain time period in lifespan of sheep. Nonlinear models provide the basis for an objective method of estimating characteristics of growth trajectory. Understanding the biological meaning of the model parameters and their relationships with other economically important production traits provide a sound basis for developing a breeding plan to modify or change the trajectory of growth (Brown et al 1976; Efe 1990; Torre et al 1992; Kocabas et al 1997; Akbas et al 1999; Esenbuga et al 2000; Bilgin et al 2004a). Estimate of parameters can be obtained by iteration even though nonlinear models are more difficult to fit than linear models (Ratkowsky 1990) because the difficulty of fitting nonlinear functions has been overcome by the developed computer technology.

Fitting growth curves to growth functions is an interesting tool for assessing different management factors or for breeding purposes. Growth curve models provide a set of parameters that describes growth pattern over time, and that estimates the expected weight of animals at a certain age (Tzeng & Becker 1981; Yakupoglu & Atil 2001; Dogan 2003; Colak et al 2006; Koncagul & Cadirci 2009; Koncagul & Cadirci 2010). In addition, the parameters obtained from growth functions are highly heritable and have been used in selection studies (Merrit 1974; Mignon-Grasteau et al 2000).

Growth characteristics of sheep have been described by nonlinear mathematical functions; such as, Brody, Gompertz, Logistic, Negative exponential and Bertalanffy growth functions in Turkish Kivircik and Daglic male lambs (Akbas et al 1999), in Awassi lambs (Tekel et al 2005), and in Karacabey Merino x Kivircik lambs (Yildiz et al 2009). Akbas et al (1999) concluded that the all four functions described the growth of male lambs quite similarly. On the other hand, Tekel et al (2005) reported that Logistic, Gompertz and Bertalanffy models described the growth of Awassi lambs better than Brody and Negative exponential models. Bilgin et al (2004b) compared Brody, Logistic, Gompertz, Bertalanffy and Richards functions to describe growth of Awassi and Morkaraman sheep. They reported that the Brody and Richards functions best described the growth of both breeds with the same accuracy. Growth trajectories of the other Turkish sheep and goat breeds have also been studied by other researchers (Keskin & Dag 2006; Topal et al 2004; Thieme et al 1999). However, the research on the growth of Norduz sheep is limited.

Therefore, this study has two folds; the first aim was to compare various nonlinear growth functions in terms of their ability for describing growth trajectory of Norduz female and male lambs from birth to 198 days of age, the second aim was to investigate and examine the growth of Norduz female and male lambs by selected nonlinear growth function.

2. Materials and Methods

Total of 179 heads Norduz lambs of 93 male lambs and 86 female lambs were used as animal material. The lambs were raised in farmer condition in Norduz Plateau of Gürpınar County in Van-Turkey. Norduz sheep is a native sheep of Eastern Anatolia. This sheep is actually distrubuted 23 villages of an area, called Norduz plateau in Van, Turkey. This research was carried out in Geçerli village in Gürpınar county, Van, Turkey. The lambs were freely nursed by their mothers and were grazed until 3-month-old age. In addition, two times in a day, alfa-alfa hay was given to the lambs after 2–week-old age. Body weight (BW) were measured in two week periods from birth to 198-d of age.

Brody, Gompertz, Logistic, Negative exponential and Bertalanffy growth curve models were fitted to the data, previously described by Hald (1952), Fitzhugh (1976), Brown et al (1976); Neter et al (1989) and Bathaei & Leroy (1996), respectively, as follows:

Brody : $BW_t = BW_A\ [1 - B\ \exp(-kt)]$,
Gompertz : $BW_t = BW_A\ \exp[(-B\ \exp(-kt)]$,
Logistic : $BW_t = BW_A/[(1 + B\ \exp(-kt)]$,
Bertalanffy : $BW_t = BW_A\ [1 - B\ \exp(-kt)^3]$,
Negative Exponential: $BW_t = BW_A - [BW_A\ \exp(-kt)]$

Where, BW_t is the body weight at age t; BW_A is the asymptotic or mature weight; B is the initial weight; k is the growth rate; t is the age in days. Since repeated measurements are generally autocorrelated, the growth models were fitted to individual lamb to remove any possible bias in the statistical inference on the growth parameters. When the analyses were completed, the model parameters were used to predict the growth data from day 1 to day 198 and correlation between the observed and the predicted growth curves were calculated. The models were compared based on the asymptotic body weight (BW_A), coefficient of determination (R^2) which shows how well a model fits the data, residual standard deviation (RSD) which measures the error in absolute terms, and correlation between the observed and the predicted body weights (r) which quantifies the degree of association between real and estimated growth curves. Calculations were carried out with non-linear regression option in the SPSS (version 5.0.1) statistical software package program with Levenberg-Marquart estimation method. Convergence criterion was the relative reduction between successive residual sums of squares, and was set to 1.0E–08. Means of individuals subjected to different environments were compared by t-test (Duzgunes et al 1987).

3. Results and Discussion

Overall means and standard errors for body weight (BW) for both sexes and type of birth by age are represented in Table 1. For both sexes and type of birth, standard error increased with age. Differences between sexes first appeared at 1 wk of age and sustained thereafter (*P*<0.01) except in 2 wk of age where the difference between the mean BWs of male and female lambs was insignificant. Over the growth period of lambs, males were heavier than females. Differences between type of birth first appeared at birth and sustained thereafter (*P*<0.01). Over the growth period of lambs, single born lambs were heavier than twin born lambs. The goodness of fit parameters obtained from the Bertalanffy, Gompertz, Brody, Negative exponential and Logistic growth curves fitted separately to individual data are presented in Table 2.

3.1. Model comparison

The R^2 values were highest for Logistic growth models indicating a significant relationship between age and weight in both sexes and types of birth, followed by Bertalanffy and Negative exponential functions. The R^2 values obtained from fitting the Gompertz and Brody growth curves were the smallest among the five functions fitted in this study. The results in this study are in conflict with the study conducted on Norduz female kids by Keskin & Daskiran (2007). They concluded that the Gompertz model was the most apropriate for describing growth trejectory of Norduz female kids. In a study of growth in broilers, Yakupoglu & Atil (2001) reported high coefficient of determination for Gompertz and Bertalanffy growth models. Topal et al (2004) stated that the Gompertz function was the best fitted for the Morkaraman breed, while the Bertalanffy function was the best for describing the growth of Awassi breed. On the other hand, Bilgin & Esenbuga (2003) compared exponential, Brody, Gompertz, Logistic, Bertalanffy and Richard models in order to describe the growth of Morkaraman sheep and concluded that the Brody model has best decribed the growth of Morkaraman sheep.

Table 1-Means (±SEM) of body weight by age and type of birth and sex in Norduz female and male lambs

Çizelge 1-Norduz erkek ve dişi kuzuların cinsiyet ve doğum tipine göre değişik yaşlardaki canlı ağırlıklarının ortalaması (±SH)

	TB[1]		Sex	
Age(Days)	S (n=143)	T (n=36)	M (n=85)	F (n=93)
1	4.6±0.05[2]	3.8±0.08	4.7±0.07	4.3±0.06
7	6.0±0.11	4.9±0.16	6.1±0.13	5.5±0.13
14	8.4±0.33	6.4±0.20	8.0±0.15*	7.9±0.50*
28	10.4±0.16	8.1±0.16	10.5±0.22	9.5±0.18
42	13.0±0.17	10.1±0.32	13.0±0.24	11.9±0.24
56	15.7±0.20	12.5±0.38	15.8±0.28	14.4±0.27
70	18.6±0.23	15.1±0.46	18.8±0.31	17.0±0.32
84	21.3±0.29	17.2±0.53	21.7±0.39	19.3±0.37
98	24.8±0.45	20.4±0.58	25.6±0.61	22.4±0.46
112	29.2±0.45	24.3±0.74	30.0±0.61	26.6±0.51
126	34.3±0.45	30.1±0.80	36.4±0.53	30.8±0.48
140	36.8±0.48	32.6±0.82	39.0±0.59	33.2±0.48
154	40.0±0.46	36.2±0.87	42.3±0.59	36.3±0.43
170	41.8±0.46	38.4±0.84	44.4±0.54	37.9±0.40
184	43.0±0.50	39.8±0.76	45.4±0.59	39.3±0.40
198	43.1±0.55	40.6±0.97	44.8±0.65	39.9±0.54

[1]TB: Type of birth (S:single, T:twin); M:male, F:female
[2]All means in each row within TB and within Sex are significantly different (*P*<0.01)
*Nonsignificant

Sengul & Kiraz (2005) reported high R^2 values for Gompertz-Laird and Logistic models in a study of growth curves of turkeys. Norris et al (2007) compared Gompertz-Laird and Logistic growth models in a study of growth in Venda and Naked Neck chickens, and found high R^2 values for the two growth models. Aggrey (2002) compared the Gompertz-Laird and Logistic growth models in a study of growth in chickens, and reported high R^2 values for the two growth models. Tekel et al (2005) concluded that Logistic, Gompertz and Bertalanffy models described growth of Awassi lambs better than Brody and Negative exponential models. Koncagul & Cadirci (2009) reported high R^2 values for Gompertz and Logistic growth functions in a study of growth curve of *Japanese quails*. On the basis of coefficient of determination in the present study to describe relationship between body weight and age, the Logistic, Bertalanffy and Negative exponential functions seemed to be appropriate.

Table 2-Comparison criteria (Mean±SE) for model selection

Çizelge 2-Model seçimi için karşılaştırma kıstasları (Ort±SH)

Parameters	TB*Sex	Bertalanffy	Brody	Gompertz	Logistic	Negative Exp.
BW_A[1]	S	72.5±2.20	142.5±11.61	47.2±5.30	49.2±0.53	797.9±578.80
	T	101.8±13.00	168.9±23.84	49.7±7.64	49.0±1.17	898.8±294.78
	F	81.0±5.84	131.7±12.75	45.1±5.63	47.2±0.55	338.0±100.69
	M	75.5±2.51	167.0±17.07	50.6±7.14	51.3±0.75	1332.1±956.55
R^2	S	0.994±0.0005	0.917±0.0107	0.876±0.0139	0.995±0.0004	0.987±0.0020
	T	0.993±0.0007	0.777±0.0289	0.788±0.0576	0.995±0.0006	0.985±0.0016
	F	0.995±0.0004	0.877±0.0158	0.825±0.0269	0.996±0.0003	0.986±0.0029
	M	0.993±0.0007	0.910±0.0154	0.895±0.0158	0.994±0.0006	0.987±0.0010
RSD	S	2.15±0.080	5.94±0.482	7.87±0.545	1.89±0.075	3.10±0.110
	T	2.04±0.107	10.55±0.949	7.81±1.292	1.75±0.104	3.01±0.129
	F	1.78±0.079	6.93±0.603	8.17±0.740	1.62±0.078	2.83±0.137
	M	2.50±0.096	6.58±0.698	7.51±0.684	2.12±0.093	3.35±0.113
r	S	0.988±0.0008	0.900±0.0366	0.890±0.0251	0.990±0.0007	0.979±0.0037
	T	0.988±0.0012	0.827±0.1080	0.701±0.0832	0.991±0.0011	0.982±0.0012
	F	0.990±0.0008	0.890±0.0474	0.795±0.0404	0.992±0.0007	0.979±0.0056
	M	0.985±0.0012	0.883±0.0546	0.916±0.0325	0.989±0.0011	0.979±0.0013
# UnConv[2]		4	41	4	2	1
%UnConv		2.2	22.9	2.2	1.1	0.5

[*]TB: Type of birth (S:single, T:twin); Sex (M:male, F:female)

[1]BW_A:asymtotic weight; R^2:multiple correlation coefficient; RSD:residual standard deviation; r: correlation between the observed and the predicted growth curves

[2]#UnConv: number of unconverged growth curves

%UnConv: percentage of unconverged growth curves

Residual standard deviations (RSD) were smallest for Logistic growth curve (Table 2). RSD was slightly larger for Bertalanffy growth model. The other models produced larger RSD for both sexes and types of birth. RSDs were very similar within the types of birth but larger for male lambs than female lambs. Yakupoglu & Atil (2001) reported smaller RSD for Gompertz model than Bertalanffy. Sengul & Kiraz (2005) found smaller RSD for MMF (Morgan-Mercer-Flodin) function compared to Richards, Gompertz, and Logistic models. Additionally, Norris et al (2007) found that the Richards model had the smaller RSD than Gompertz and Logistic models. Keskin & Daskiran (2007) reported similar estimates of RSD for the Logistic and Gompertz growth models in a study of growth of Norduz female kids. Koncagul & Cadirci (2009) reported that the Richards, Logistic and Gompertz models produced similar estimates of RSD. Yildiz et al (2009) found that the Gompertz model described the growth of crassbred lambs (Karacabey Merino x Kivircik) the best comparing to Logistic ve linear model. In the present study, the smallest RSD were obtained from the Bertalanffy and Logistic functions. Based on the RSD in this study, the Bertalanffy and Logistic models seemed to be appropriate for describing the growth of Norduz lambs.

The appropriateness of the models for describing the growth of animals has been decided by arguing on the asymptotic body weights (BW_A) predicted by the models fitted (Lopez de Torre et al 1992; Yakupoglu & Atil 2001; Norris et al 2007; Koncagul & Cadirci 2009). Lopez & Torre et al (1992) assessed the best fitting growth models by comparing the observed 60 to 90 months average weight and the BW_A predicted by the models. Yakupoglu & Atil (2001) recommended that small estimate of BW_A should be desirable for deciding on the best fit model. In the present study, based upon the decision of the choice of the most appropriate model, differences between the observed BW_A (average of 184[th] and 198[th] day in Table 1) and the predicted BW_A (Table 2) were tested using t-test procedure. Largest values of the BW_A parameter were observed under the Negative exponential model (P<0.05), followed by Brody and Bertalanffy growth models. The Gompertz and

Logistic models produced meaningful and closer estimates to observed mature body weight of Norduz lambs (Table 2). Based on the t-test results, the Bertalanffy, Brody and Negative exponential models severly overestimated the BW_A. Although no significant differences were observed between the observed and the predicted asymptotic BW by the Logistic and Gompertz model, the standard errors of the estimates of BW_A by Gompertz model were quite higher than those obtained by Logistic growth model. Based on the BW_A in this study, the Logistic models seemed to be appropriate for describing the growth of Norduz lambs.

In the present study, decision on appropriateness and the ability of the models for describing the growth trejectory of Norduz lambs has been made by examining the correlations (r) between the observed and the predicted growth curves (Table 2). After obtaining the parameters from each model, daily (from day 1 to day 198 in two weeks interval) body weights were predicted using the parameters produced by the models. Then, correlations between the observed and the predicted BWs were calculated for sexes and types of birth for each model. Regarding Table 2, it is clear that Logistic growth model produced the highest r values, followed by Bertalanffy and Negative exponential models. The smallest estimates of r were obtained fitting of Gompertz and Brody models.

The overall assessment of the growth models on the basis of the comparison criteria of R^2, RSD, r, and BW_A, used in the present study, the Logistic growth model seemed to be the most appropriate model to describe the association between age and live weight, and to explain the growth trajectory of Norduz female and male lambs. Based on the above assessments, the Logistic growth model was further used to assess the parameters of the growth curves of Norduz female and male lambs.

3.2. Growth of Norduz lambs

Since consecutive or repeated measurements are usually autocorrelated, the growth models were fitted to individual lambs to remove possible bias in the statistical inference on the growth parameters. Then, the estimated parameters were averaged over each main effect of the sex and types of birth. Comparisons were made within the sex and types of birth using t-test procedure. The levels of interaction of environmental conditions are not reported here because the all interaction effects were insignificant. The Logistic growth curves are shown in Figure 1a for type of birth and in Figure 1b for sexes. As seen in curves, fitted lines are close to the observed values. The values estimated by Logistic model for the parameters BW_A, r, RSD, and R^2 are given in Table 2 (the sixth column). The other model parameter estimates are shown in Table 3.

Table 3-Means (±SE) of growth curve parameters of Logistic function by type of birth and sex in Norduz lambs

Çizelge 3-Norduz kuzularında, Lojistik fonksiyonun büyüme eğrisi parametrelerinin ortalamaları (±SH)

Factors			
TB*	**BW_A**	**K**	**ti**
BW_A	---	-0.4108	0.6344
K	-0.6443	---	-0.8273
ti	0.7084	-0.8572	---
Sex			
BW_A	---	-0.5690	0.7091
K	-0.6167	---	-0.7732
ti	0.6857	-0.8743	---

[*]TB: Type of birth (S:single, T:twin); Sex (M:male, F:female)
[a]Different subscripts indicated significant difference (*P*<0.001) within row within TB and within Sex

There was no differences between growth parameters for type of birth, except for the age at maximum growth (ti). Although single and twin born lambs had similar growth rate (K) and similar asymptotic body weight (BW_A), single born lambs reached age at maximum growth about 17 days earlier than twin born lambs. It can be expected that individual with lower K would reach ti later than individual with higher K.

In the present study, Norduz female lambs reached ti later, but they were able to have same BW_A probably due to the environment provided to them. There was significant (*P*<0.001) differences between growth parameters for sex, except for the age at maximum growth (ti). Male lambs had higher K and BW_A than female lambs although female lambs and male lambs had similar (ti).

Correlations among growth curve parameters for sex and type of birth are given in Table 4. The relationship between BW_A and K has biologically important meanings (Lopez de Torre et al 1992). Moderate negative correlations for both single born lambs and twin born lambs observed between BW_A and K indicate that type of birth is not a factor affecting the K and BW_A in Norduz sheep.

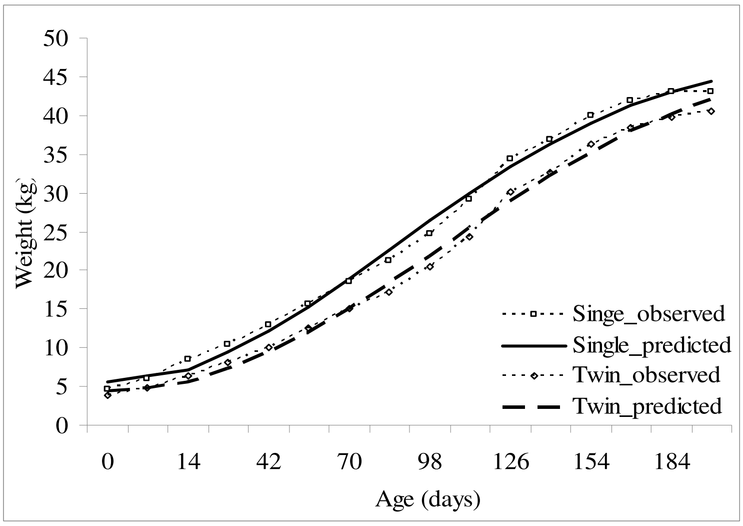

Figure 1a-Measured and estimated growth curves of single and twin born lambs by Logistic model
Şekil 1a-İkiz ve tekiz doğan kuzuların gözlemlenen ve Lojistik model tarafından tahmin edilen büyüme eğrileri

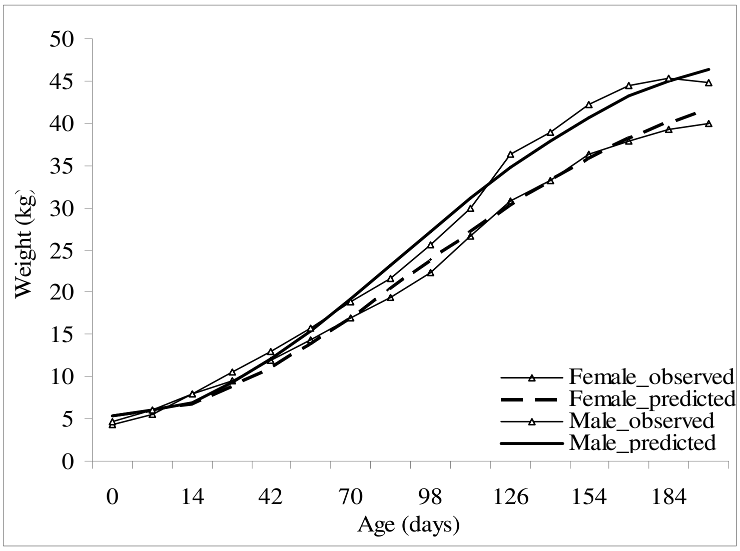

Figure 1b-Measured and estimated growth curves of male and female lambs by Logistic model
Şekil 1b-Erkek ve dişi doğan kuzuların gözlemlenen ve Lojistik model tarafından tahmin edilen büyüme eğrileri

That is to say, faster growing lambs do not attain a larger mature weight compared to those slower growing lambs.

In regard to sex factor, this statement is not hold because male lambs grew faster and attained larger mature weight than female lambs showing that sex is the main factor affecting the growth of Norduz lambs. In the present study, interaction between sex and type of birth was examined, and preliminary analysis showed that the interaction was insignificant. Thus, all the comparisons were made within the main factors. If the objective in a

Table 4-Correlation among the model parameters of Logistic function by type of birth and sex in Norduz lambs
Çizelge 4-Norduz kuzularında, Lojistik fonksiyonun büyüme eğrisi parametreleri arasındaki korelasyonlar

	TB		Sex	
	S	T	F	M
BW_A	49.2±0.53	49.0±1.17	47.2±0.55^{a}	51.3±0.75^{b}
K	0.023±0.0003	0.022±0.0005	0.022±0.0003^{a}	0.024±0.0004^{b}
ti	92.6±1.48^{a}	109.2±3.36^{b}	98.3±2.08	93.5±1.98

*TB: Type of birth (S:single, T:twin); Sex (M:male, F:female)
#Upper triangle within TB is for Single birth, and lower triangler is for Twin birth
#Upper triangle within Sex is for female lambs, and lower triangler is for male lambs

breeding program is to increase the mature body weight, evaluation should be made within sex without considering type of birth in Norduz sheep.

4. Conclusion

Logistic growth curve is appropriate for describing the age-body weight relationship in the Norduz sheep. The results showed evidence that there are differences in the growth of female and male lambs whereas type of birth is not resulted in any differences. The development of growth curves for this indigenous sheep provides information about mature weights and growth rates of this sheep. Further studies are required to estimate genetic parameters of the growth curves, so that, in development of a breeding program growth curve parameters could be used in selection decision for genetic improvement.

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